The Reactions $^{13}C(p,\gamma)$ ^{14}N and $^{10}B(p,\alpha)$ ^{7}Be

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Explosives containing ^{14}N inside cargo should be inspected for Homeland Security mainly at airports, but also at other ports. In order to perform such an inspection a nuclear resonance absorption technique has been proposed [1] where the ^{14}N is bombarded (interrogated) by a monoenergetic γ-ray beam where the cross section is very high. The way this can be done is by preparing laboratory energy 1.76 MeV protons in a storage ring, which then impinges on a very pure ^{13}C target to form monoenergetic γ-rays because of a very narrow resonance in the ^{14}N nucleus. These γ-rays are emitted at a laboratory angle of 80.7° and an energy of 9.17 MeV, and serve as the beam that is needed to inspect cargo containing ^{14}N. Hence a high flux monoenergetic proton beam produces a monoenergetic γ-beam, suitable for rapid cargo inspection, via the reaction ^{13}C(p, γ_0) ^{14}N. The fact that the recoil nucleus (here ^{14}N) is in its ground state will be indicated by a subscript "0" from now on. The current evaluation focuses on the very narrow resonance and parameterizes the background of various other resonances for proton energies up to 2 MeV.

The result of an R-matrix fit to known resonances is shown in Fig. 1. Since the cross section is plotted logarithmically, the height of the resonance at 1.76 MeV proton energy is underemphasized. An evaluated cross-section file with angular distributions in ENDF format is prepared for the reaction ^{13}C(p, γ_0) in the proton energy range 0.01–2 MeV.

As a separate project, the reaction $^{10}B(p,\alpha)^{7}Be$ is evaluated because it is relevant to thermonuclear explosions. This evaluation comes from the first multichannel R-matrix analysis of the reactions in the ^{11}C system ever performed. An evaluation of the S-factor for ^{10}B(p, α_0) had been done earlier [2], because of its importance in astrophysics.

An R-matrix fit of experimental nuclear data on the elastic scattering reaction $^{10}B(p,p_0)$ ^{10}B and of the exothermic reaction $^{10}B(p,\alpha_0)$ is performed. Data sets from 10 experimental references with 1845 data points are used. The overall χ^2 per degree of freedom for all data entered is 2.2.

The evaluated $^{10}B(p,\alpha_0)$ cross section is presented in Fig. 1. The large renormalizations needed for the modern Angulo 1993 and Youn 1991 data may not be a concern as it is known that these reactions disagree by large factors. It is comforting that the Chiari 2001 data on elastic scattering, which is available above 0.5 MeV, determine the normalizations of the Angulo 1993 and Youn 1991 data, while itself fitting with normalizations within 4% of the experimental value. The normalization of the $^{10}B(p,\alpha_0)$ data is hence strongly constrained by the $^{10}B(p,p_0)^{10}B$ data. The exact normalizations of the $^{10}B(p,\alpha_0)$ data above 1.5 MeV have changed considerably at various stages of the analysis.

An evaluated cross-section file with angular distributions in ENDF format is prepared for the reactions $^{10}B(p,\alpha_0)$ and $p^{10}B$ elastic scattering in the energy range 0.01–3 MeV. Maxwellian averaged cross sections in nuclear data interface (NDI) format are prepared for the reaction $^{10}B(p,\alpha_0)$. These may not be very accurate below a temperature of about 10 keV. Details of the analysis are available in Ref. [3].

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[1] R.E. Morgado, et al., "Prototype Explosives-Detection System Based on Nuclear-Resonance Absorption in Nitrogen," Los Alamos National Laboratory report LA-12776-MS (June 1994); D. Vartsky, et al., *Nucl. Phys. A* **505**, 328 (1989); W. Biesot and P.B. Smith, *Phys. Rev. C* **24**, 6 (1981).

[2] C. Angulo, et al., *Nucl. Phys. A* **656**, 3 (1999).
[3] P.R. Page, "^{11}C Nuclear Data Evaluation," Los Alamos National Laboratory report LA-UR-05-6250 (August 2005).

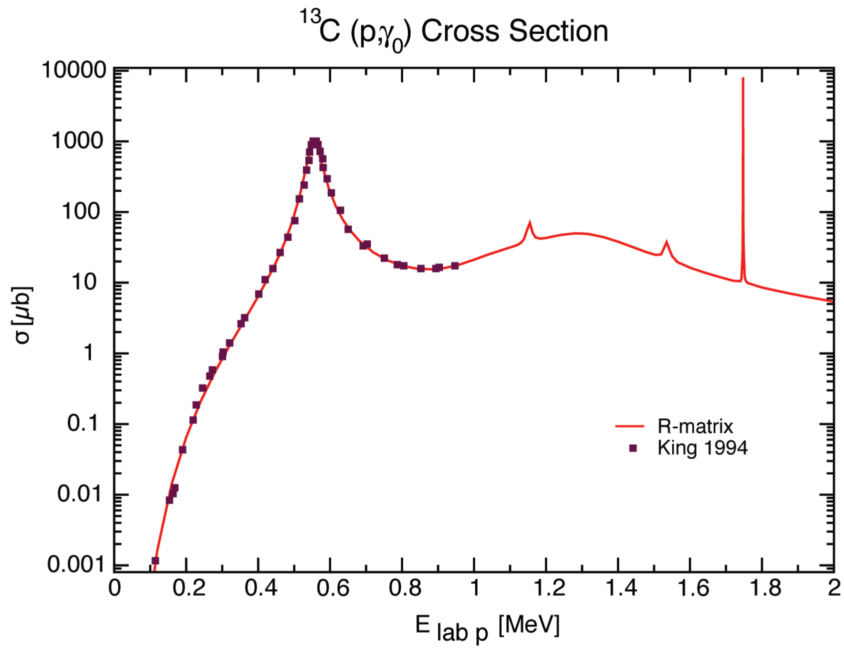

Fig. 1.
The R-matrix analysis cross section (red curve) in microbarns for the $^{13}C(p, \gamma_0)^{14}N$ reaction up to a proton laboratory energy $E_{lab\ p}$ of 2 MeV, with the one set of experimental (integrated) cross-section data entered in the analysis.

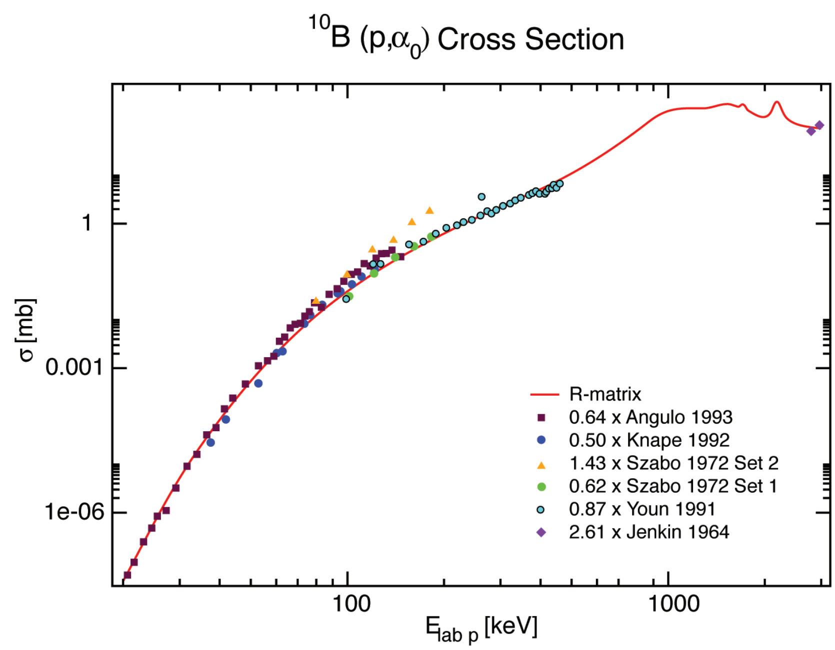

Fig. 2.
The R-matrix analysis cross section (red curve) in millibarns for the $^{10}B(p, \alpha_0)^7Be$ reaction up to a proton laboratory energy $E_{lab\ p}$ of 3 MeV, with the six sets of experimental (integrated) cross-section data entered in the analysis. The numerical factors in front of the experimental data labels indicate that the data must be multiplied by those factors to obtain the points plotted.